

U.S. Patent Application Serial No. 09/642,883  
Response Under 37 C.F.R. §1.116 dated December 22, 2003  
Reply to the Final Rejection of March 20, 2003  
Attorney's Docket No. 001035

**Amendments to the Claims**

This listing of claims will replace all prior versions, and listings, of claims in the application:

**Listing of Claims:**

Claim 1 (Canceled).

Claim 2 (Currently Amended): ~~The~~ A plane diffraction grating ~~according to claim 1 with grooves formed on a surface thereof, the plane diffraction grating being~~ rotated about a rotational axis which is normal to the surface, and being characterized in that a profile of the grooves at a radial area is determined depending on an azimuthal position  $\phi$  of the area about a rotational center defined as a foot of the rotational axis on the surface of the plane diffraction grating for maximizing a diffraction efficiency of the radial area,

wherein the plane diffraction grating is a blazed type, and a blaze angle  $\theta_0$  of the grooves in an area along an original line at the azimuthal angle  $\phi = 0$  which is perpendicular to the grooves is set as:

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal, and

a blaze angle  $\theta\phi$  of the grooves in an area along a line at the azimuthal position is set as

$$\sin \theta_{\phi} = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 3 (Previously Presented): The plane diffraction grating according to claim 2, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the original line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

$m_b$  is the diffraction order,

$\lambda$  is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \alpha},$$

$$\delta_{\phi} = 1 - n_{\phi},$$

$n_{\phi}$  is the average refractive index of the multiple-layer coating.

Claim 4 (Currently Amended): ~~The A~~ plane diffraction grating according to ~~claim 1~~ with grooves formed on a surface thereof, the plane diffraction grating being

rotated about a rotational axis which is normal to the surface, and being characterized in that a profile of the grooves at a radial area is determined depending on an azimuthal position  $\phi$  of the area about a rotational center defined as a foot of the rotational axis on the surface of the plane diffraction grating for maximizing a diffraction efficiency of the radial area,

wherein the plane diffraction grating is a laminar type, and a depth  $h_\phi$  of the grooves in an area along a line at the azimuthal angle  $\phi$  is set as

$$h_\phi = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where  $\lambda$  is the wavelength of the light diffracted by the area,  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal.

Claim 5 (Previously Presented): The plane diffraction grating according to claim 4, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

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$m_b$  is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \beta},$$

$$\delta_\phi = 1 - n_\phi,$$

$n_\phi$  is the average refractive index of the multiple-layer coating.

Claim 6 (Canceled).

Claim 7 (Currently Amended): The An optical system ~~according to claim 6,~~  
comprising:

a plane diffraction grating having grooves on a surface of the plane  
diffraction grating whose profile at an area is determined depending on an  
azimuthal position  $\phi$  of the area about a rotational center defined as a foot of a  
rotational axis which is normal to the surface for maximizing a diffraction efficiency  
at the area;

a mechanism for rotating the plane diffraction grating about the rotational  
axis;

an incidence optical system for casting a converging beam of light on a point  
of the surface of the plane diffraction grating, the point being apart from the  
rotational center.

wherein the plane diffraction grating is a blazed type, and a blaze angle  $\theta_0$  of the grooves in an area along an original line at the azimuthal angle  $\phi=0$  which is perpendicular to the grooves is set as:

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal, and

a blaze angle  $\theta_\phi$  of the grooves in an area along a line at the azimuthal position  $\phi$  is set as:

$$\sin \theta_\phi = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 8 (Previously Presented): The optical system according to claim 7, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the original line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

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$m_b$  is the diffraction order,

$\lambda$  is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha},$$

$$\delta_\phi = 1 - n_\phi,$$

$n_\phi$  is the average refractive index of the multiple-layer coating.

Claim 9 (Currently Amended): ~~The~~ An optical system ~~according to claim 6,~~  
comprising:

a plane diffraction grating having grooves on a surface of the plane diffraction grating whose profile at an area is determined depending on an azimuthal position  $\phi$  of the area about a rotational center defined as a foot of a rotational axis which is normal to the surface for maximizing a diffraction efficiency at the area;

a mechanism for rotating the plane diffraction grating about the rotational axis;

an incidence optical system for casting a converging beam of light on a point of the surface of the plane diffraction grating, the point being apart from the rotational center,

wherein the plane diffraction grating is a laminar type, and a depth  $h_\phi$  of the grooves in an area along an original line at the azimuthal angle  $\phi$  is set as

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$$h_{\phi} = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where  $\lambda$  is the wavelength of the light diffracted by the area,  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal.

Claim 10 (Previously Presented): The optical system according to claim 9, wherein:

the surface of the plane diffraction grating is covered with a multiple-layer coating to improve reflectivity;

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

$m_b$  is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_{\phi} - \delta_{\phi}^2) / \cos^2 \beta},$$

$$\delta_{\phi} = 1 \cdot n_{\phi},$$

$n_{\phi}$  is the average refractive index of the multiple-layer coating.

Claim 11 (Cancelled).

Claim 12 (Currently Amended): ~~The plane diffraction grating~~ A method of producing method according to claim 11, a plane diffraction grating having grooves on a surface thereof whose profile at an area is determined depending on an azimuthal position  $\phi$  of the area about a rotational center defined as a foot of a rotational axis for maximizing a diffraction efficiency of the area, the method comprising the steps of:

coating a substrate with a photo-resist layer and forming a photo-resist mask from the photo-resist layer according to a preset pattern of groove arrangement;

covering the photo-resist mask with a sector mask having an opening of a narrow sector whose apex is set at the rotational center;

etching the substrate over the sector mask with an appropriate etching condition depending on a rotational position of the sector mask about the rotational center;

rotating the sector mask by an angle of the apex of the narrow sector; and repeating the etching process and the mask rotating process until the narrow sector sweeps the surface of the substrate.



wherein the plane diffraction grating is a blazed type, and the etching condition in the etching process is such that:

a blaze angle  $\theta_0$  of the grooves in an area along an original line at the azimuthal angle  $\phi = 0$  which is perpendicular to the grooves is set as

$$\theta_0 = \frac{\alpha + \beta}{2},$$

where  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal, and

a blaze angle  $\theta_\phi$  of the grooves in an area along a line at the azimuthal position  $\phi$  is set as

$$\sin \theta_\phi = \sin \theta_0 \sqrt{\frac{1 + \tan^2 \phi}{1 + \tan^2 \phi \sin^2 \theta_0}}.$$

Claim 13 (Previously Presented): The plane diffraction grating producing method according to claim 12, wherein the surface of the plane diffraction grating is then covered with a multiple-layer coating to improve reflectivity, and:

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the original line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = 2d_{b\phi} R_{\alpha\phi} \cos(\alpha - \theta_0)$$

where

$m_b$  is the diffraction order,

$\lambda$  is the wavelength of the light diffracted by the area,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha},$$

$$\delta_\phi = 1 - n_\phi,$$

$n_\phi$  is the average refractive index of the multiple-layer coating.

Claim 14 (Currently Amended): ~~The plane diffraction grating~~ A method of producing method according to claim 11, a plane diffraction grating having grooves on a surface thereof whose profile at an area is determined depending on an azimuthal position  $\phi$  of the area about a rotational center defined as a foot of a rotational axis for maximizing a diffraction efficiency of the area, the method comprising the steps of:

coating a substrate with a photo-resist layer and forming a photo-resist mask from the photo-resist layer according to a preset pattern of groove arrangement;

covering the photo-resist mask with a sector mask having an opening of a narrow sector whose apex is set at the rotational center;

etching the substrate over the sector mask with an appropriate etching condition depending on a rotational position of the sector mask about the rotational center;

rotating the sector mask by an angle of the apex of the narrow sector; and

repeating the etching process and the mask rotating process until the narrow sector sweeps the surface of the substrate,

wherein the plane diffraction grating is a laminar type, and the etching condition in the etching process is such that:

a depth  $h_\phi$  of the grooves in an area along a line at the azimuthal angle  $\phi$  is set as

$$h_\phi = \frac{\lambda}{2(\cos \alpha + \cos \beta)},$$

where  $\lambda$  is the wavelength of the light diffracted by the area,  $\alpha$  is an angle of an incident ray from a normal to the surface of the plane diffraction grating in the area, and  $\beta$  is an angle of a diffraction ray from the normal.

Claim 15 (Previously Presented): The plane diffraction grating producing method according to claim 14, wherein the surface of the plane diffraction grating is then covered with a multiple-layer coating to improve reflectivity, and:

a unit thickness  $d_{b\phi}$  of the multiple-layer coating in the area along the line at the azimuthal angle  $\phi$  satisfies the equation:

$$m_b \lambda = d_{b\phi} (R_{\alpha\phi} \sin \alpha + R_{\beta\phi} \sin \beta),$$

where

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$m_b$  is the diffraction order,

$$R_{\alpha\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \alpha}, \quad R_{\beta\phi} = \sqrt{1 - (2\delta_\phi - \delta_\phi^2) / \cos^2 \beta},$$

$$\delta_\phi = 1 - n_\phi,$$

$n_\phi$  is the average refractive index of the multiple-layer coating.